COMPARISON TESTING OF ENVIRONMENTALLY FRIENDLY CARC COATING SYSTEMS OVER ALUMINUM SUBSTRATES

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ABSTRACT

The Chemical Agent Resistant Coating (CARC) system is designed for application to many components on Army vehicles. Variations in the CARC system to reduce VOC and hazardous material usage are desirable from a cost standpoint. The Industrial Operations Command (IOC), through the supervision of the Centers of Technical Exchange (CTX) program, tasked Ocean City Research Corporation to complete an evaluation of the MIL-P-53030 water-reducible epoxy primer and the MIL-P-53022 solvent-based epoxy primer over chromate conversion coated (CCC) and non-CCC aluminum surfaces. In all, six accelerated performance tests and two physical properties tests were performed on twenty-six (26) different coating system combinations. This paper presents results and conclusions from the accelerated corrosion testing and natural marine weathering tests only. Variations in the performance of the CARC system were noted. The most significant variables affecting CARC system performance were the aluminum alloy tested and cleaning methods for the samples. Differences were observed, although minor, between the two primer formulations. The conclusions of this work demonstrate the feasibility of modifying the CARC system for some applications to better address environmental and worker health issues.

BACKGROUND

In 1995 Red River Army Depot (RRAD) implemented a revised process for applying the CARC system on 5000 series aluminum hulled vehicles. The process eliminated the need for chromate conversion coatings. The revised process called for garnet blasting to achieve a specified surface profile, cleaning with an aqueous cleaner, application of MIL-P-53022 epoxy primer, and application of the MIL-P-46168 polyurethane topcoat. A water-reducible epoxy primer (MIL-P-53030) is approved for use in the CARC system, but its performance has not be proven in the modified RRAD process for 5000 series aluminum. A new water-reducible polyurethane CARC coating is also being developed to help reduce depot VOC emissions. Also, the RRAD process has not been significantly examined for use with other aluminum alloys, such as 2000 series used for road wheels, 6000 series angle supports, or 7000 series for turret components.

The Industrial Operations Command (IOC), through the supervision of the Centers of Technical Exchange (CTX) program, tasked Ocean City Research Corporation to complete an evaluation of the MIL-P-53030 water-reducible epoxy primer over CCC and non-CCC aluminum surfaces. The long-term performance of the water-reducible epoxy primer has not been quantified in comparison to the solvent-based primer for the modified RRAD coating process. The cost savings associated with environmental and worker protection measure reductions by using the water reducible primer can only be realized if the primer provides adequate CARC system durability.

OBJECTIVES

The short and long-term objectives of this study were to:

- Characterize any CARC system performance differences realized by using the MIL-P-53030 water reducible primer in place of the MIL-P-53022 solvent based primer.
- Investigate the applicability of the RRAD coating process for other aluminum alloys.
- Minimize the VOC produced by using the CARC system.
- Maintain Vehicle Readiness and Durability.

TECHNICAL APPROACH

The CARC specification, MIL-C-53072 "Chemical Agent Resistant Coating (CARC) System Application Procedures and Quality Control Inspection," dictates the use of four steps in the CARC coating system. The subject research investigated several CARC system variations over aluminum substrates. Table 1 identifies the approved processes and materials for the CARC system and shows the variables included in this program.

Table 1. MIL-C-53072 - CARC System over Aluminum Substrates

CARC System Step	Approved Processes and Materials	Test Variables
Cleaning	• TT-C-490 & MIL-T-704, Mechanical, Solvent, Emulsion, Vapor Degreasing	• Aqueous Alkaline Cleaner after Garnet Blast • Aqueous Alkaline Cleaner after Walnut Shell Blast
Pretreatment	• DOD-P-15328 & MIL-C-8514, Wash Primers • MIL-C-5541, Chromate Conversion Coating • MIL-A-8625, Anodizing	• MIL-C-5541, Chromate Conversion Coating • none
Primer	• MIL-P-23377, Chemical Resistant • MIL-P-53022, Solvent based • MIL-P-53030, Water reducible • MIL-P-85532, Low VOC	• MIL-P-53022, Solvent based • MIL-P-53030, Water reducible
Topcoat	• MIL-C-22750, epoxy Interior • MIL-C-46168, 2 component polyurethane • MIL-C-53039, moisture cure polyurethane • MIL-C-64159, water reducible 2 component polyurethane	• MIL-C-22750, epoxy Interior • MIL-C-53039, moisture cure polyurethane • MIL-C-64159, water reducible 2 component polyurethane

Four different aluminum alloys were selected for this testing. These were alloys 5086, 2024, 7075, and 6061. These or similar alloys comprise many of the vehicle components maintained at Army Depots.

Since the CARC coating system is designed for both aluminum and steel substrates it is important to note that aluminum alloys typically corrode at a rate 2 orders of magnitude less than steel. Among the alloys of aluminum, alloy 2024 has a corrosion rate more than twice that of 5086 and 6061. Knowing this, it would not be surprising to expect CARC corrosion performance differences among different metals or alloys.

Figure 1 shows the average maximum values for visual scribe cutback after six months of testing. The bars represent the maximum distance from the edge of the original scribe that corrosion has visually progressed under the film. All systems identified were tested, so several show zero cutback to date. All of the data shown is for garnet blasted panels that have the same topcoat within each alloy group. The X-axis shows the alloys tested with and without the CCC. Also note that the Y-axis maximum value is only 7mm.

Looking at figure 1, the largest differences in performance are attributable to the alloy type. The 7075 alloy shows scribe cutback under all CARC variations while the 5086 alloy shows no cutback to date. The CCC did improve performance over the 2024, 6061, and 7075 alloys. The difference in performance between the water-reducible and the solvent-borne primers is marginal at best and tends to favor the water-reducible in this test.

Salt Fog Exposure Testing

No through film corrosion was observed on any of the coating systems. Light density blistering was observed around the intentional scribes of some systems after 1500 hours. Alloys 2024, 6061, and 7075 without CCC showed this blistering. These same alloys with the CCC did not blister. No panels showed any other significant deterioration aside from the scribe cutback results.

Figure 2 shows the scribe cutback data after 2000 hours of salt fog testing. The chart parameters and systems are identical to figure 1 except for the maximum Y-axis value of 14mm. The largest trend in performance is seen with the addition of CCC to the CARC systems. In all cases the cutback was reduced by the use of a CCC. The 7075 alloy is more susceptible to underfilm corrosion than the other alloys tested. Use of the water-reducible primer caused a marginal reduction in overall system performance.

Cyclic Corrosion Testing

Following 20 cycles of testing none of the coating systems showed any visual signs of corrosion, blistering, or cutback from the scribe. At the 40 cycle inspection the coatings were beginning to show underfilm corrosion at the scribes. The results after 74 cycles are presented in figure 3. The failures are limited to cutback at the scribes only. Notice the Y-axis scale extends to 18mm.

Figure 3 shows that 2024 aluminum without the CCC had the largest cutback. The trend of CCC improving cutback resistance is not as clear in this data as from other performance tests. The difference between the primer types is, however, more pronounced based on these results. The water-reducible primer was not as durable as the solvent -borne primer. The corrosion shown for the 5086 aluminum was minimal for all variations of the CARC system.

CONCLUSIONS

The following conclusions were made based on the results of the accelerated performance and marine atmospheric exposure tests to date.

- Negligible differences were observed between the water-reducible and solvent-based primers over the 5086 aluminum alloy or over the 6061 alloy with a chromate conversion coating.
- The water-reducible primer allowed more underfilm corrosion than the solvent-based primer over non-chromate conversion coated 6061 aluminum.

- In the GM 9540P accelerated corrosion test the water-reducible primer allowed more underfilm corrosion than the solvent-based primer over the 2024 alloy.
- In general the 2024 and 7075 alloys were more prone to underfilm corrosion than the 6061 or 5086 alloys. The 5086 was the least corrosion prone of all alloys tested.
- The chromate conversion coating generally aided in the performance of the 2024, 6061, and 7075 alloys. Minimal differences were noticed over the 5086 alloy with the addition of the chromate conversion coating.

Recommendations

The historically used CARC systems have included cleaning, a chromate conversion coating, and solvent based coatings. The results herein demonstrate that satisfactory performance of CARC systems can be obtained over some aluminum alloys with more environmentally acceptable materials. The substitution of chromate conversion coating application with abrasive blasting and alkaline cleaning, and the use of water reducible coating formulations are two examples of this trend. The long-term performance of these alternative CARC systems should be monitored to determine that acceptable vehicle performance is maintained. We suggest that follow-on reports be generated for the samples that will remain under marine atmosphere exposure for several years. This will quantify the performance differences and aide in the CARC system decisions for Army materiel.

Figure 1
6 months Marine Exposure

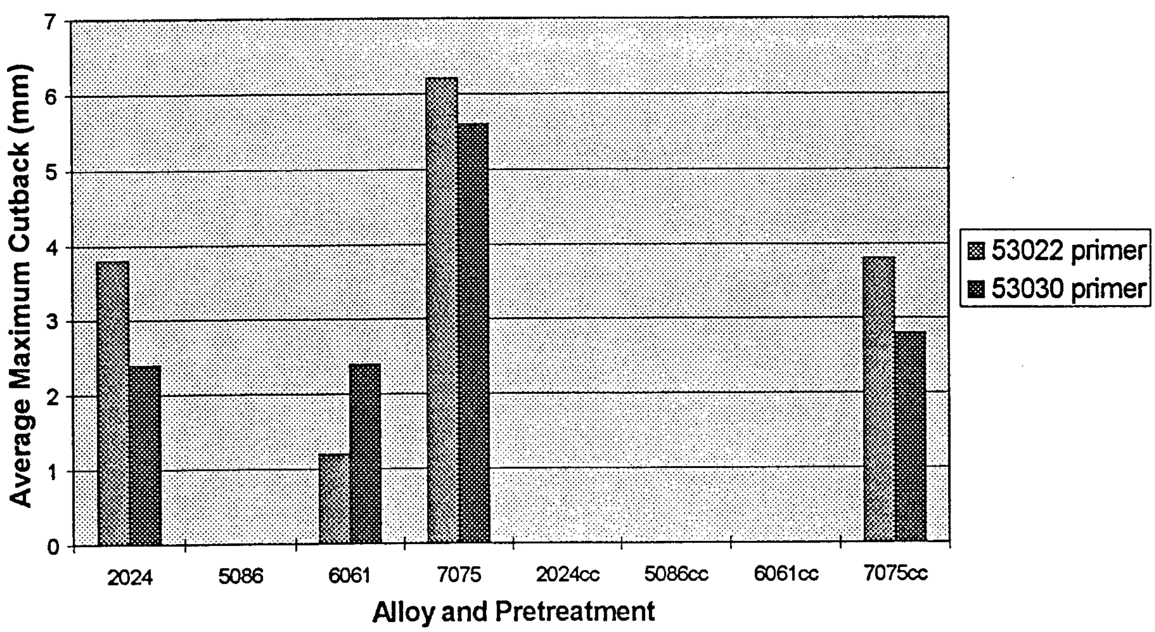

Figure 2
2000 hours salt fog

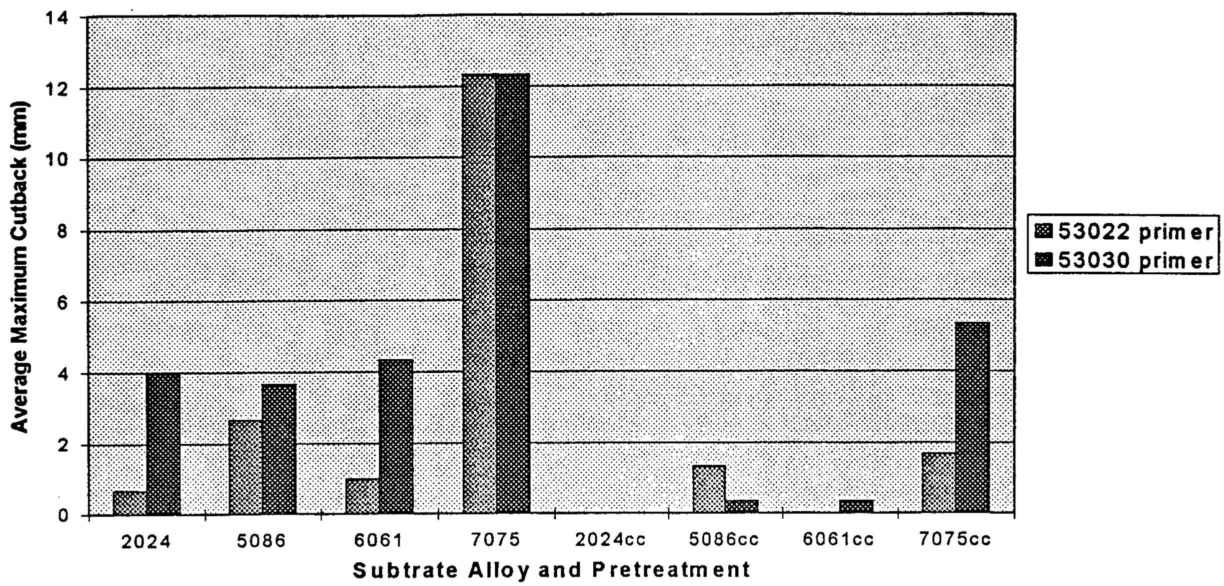

Figure 3
74 cycles GM9540P Cyclic Corrosion Test